19. Life Cycle of Stars

Can you recall?

1. What is a galaxy?
2. What are the different constituents of our solar system?
3. What are the major differences between a star and a planet?
4. What is a satellite?
5. Which is the star nearest to us?

We have learnt about the structure of the universe in earlier standards. Our solar system is situated in a galaxy. A galaxy is a collection of billions of stars, their planetary systems and interstellar clouds which are present in the empty spaces between stars. The universe is made up of innumerable such galaxies. Galaxies differ in structure and shape. We can divide them into three types : spiral, elliptical and irregular galaxies. Our galaxy is a spiral galaxy and is called the Milky Way and Mandakini. A spiral galaxy is show in figure 19.1

19.1 The figure shows a spiral galaxy. Our solar system is situated in a similar galaxy.

How did we obtain all this information about the universe?

If we look at the sky at night we see only planets and stars, then how did we get information about the other components of the universe? The answer to the question is telescopes. Several telescopes are placed on the surface of the earth, while some others are kept aboard manmade satellites which are orbiting the earth in fixed orbits. As these telescopes are situated above the earth's atmosphere they can observe astronomical objects more effectively. Astronomers study the observations made by all these telescopes to obtain detailed information about the universe. We are going to learn about all this in higher standards. Here, let us learn about the properties of stars and their life cycle.

Properties of stars : At night, we can see about 4000 stars with our naked eyes. Sun is an ordinary star among them. The reason to call Sun an ordinary star is that even though it appears to be larger than all others stars in the sky because of its being nearest to us, there are bilions of stars which have higher or lower mass size and temperature than those of the Sun. Stars are gigantic spheres of hot gas. Some properties of the Sun are given in the table below. Hydrogen makes up for 72% of the mass of the Sun while helium is 26%. The rest 2% is made up of elements heavier than helium.

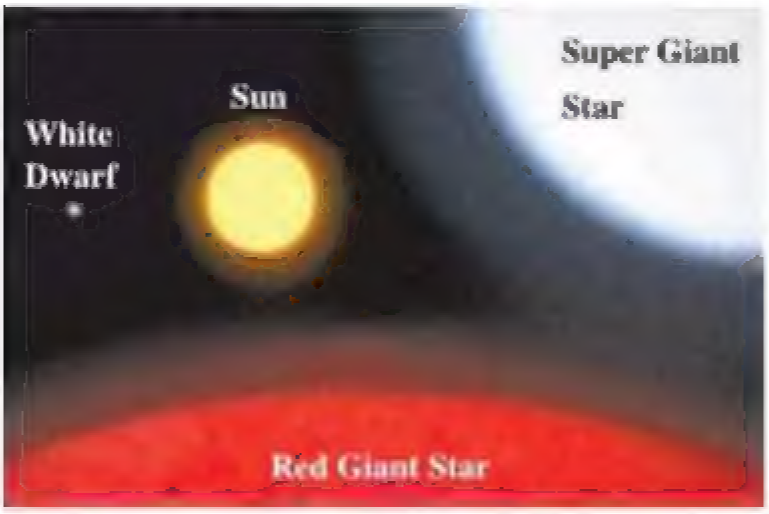
Do you know?

Our galaxy has about 10^{11} stars. Its shape is like a disc with a bulge in the centre and its diameter is about 10^{18} km. The solar system is situated at a distance of 2×10^{17} km from its centre. The galaxy is rotating around an axis passing through its centre and perpendicular to the disc. Its period of rotation is about 2×10^{8} yrs.

Properties of the Sun :

Mass	2×10^{30} kg
Radius	695700 km
Surface temperature	5800 K
Temperature at the centre	1.5×10^{7} K
Age	4.5×10^{9} yr

The mass of the Sun is about 3.3 lakh times that of the earth and its radius is 100 times that of the earth. Other stars have masses between $\frac{1}{10}$ $(\frac{M_{Sun}}{10})$ that of the Sun and 100 times that of the Sun (100 M_{Sun}) and their radii can between $\frac{1}{10}$ to 1000 times the radius of the Sun. (Fig. 19.2)



19.2 A comparison of sizes of different stars

Do you know?

The masses of other stars are measured with respect to the mass of the Sun. This means that the mass of the Sun, written as M_{Sun} is used as the unit of mass.

The age of the Sun and other stars, which is the time elapsed after their formation, can be between a few million years to a few billion years. If the properties of the Sun had changed in its life time, it would have caused changes in the properties of the earth and in the life on the earth. Detailed studies of the properties of the earth have led scientists to conclude that the properties of the Sun have remained unchanged over its lifetime i.e. the past 4.5 billion years. According to the studies made by astromomers, these properties will slowly change in further after 4.5 billion years.

Birth of stars

Huge clouds of gas and dust are present in the empty spaces between stars in a galaxy. These are called interstellar clouds. Figure 19.3 shows a picture of such clouds taken by the Hubble space telescope. Scientists use the unit of light year for measuring large distances. **A light year is the distance travelled by light in one year.** As the speed of light is 3,00,000 km/s, the light year is equal to 9.5×10^{12} km. The sizes of interstellar clouds are about a few light years, i.e. light takes a few years to go from one end of a cloud to the other. From this you can imagine the huge size of the cloud.

19.3 A picture of interstellar clouds taken by the Hubble space telecope

Due to some disturbance, these clouds start contracting. Because of the contraction, their density starts increasing and their temperature also starts to increase and a dense sphere of hot gas is formed from the cloud. Once the temperature and density at the centre of the sphere increase sufficiently, nuclear energy (energy generated through fusion of atomic nuclei) generation starts there. Because of this energy generation, the gas sphere becomes self luminous and a star is formed or we can say that a star is born. In the Sun, this energy is generated by the fusion of hydrogen nuclei to form helium nuclei. This means that the hydrogen at the centre of the star acts as a fuel and energy is generated by the burning of this fuel.

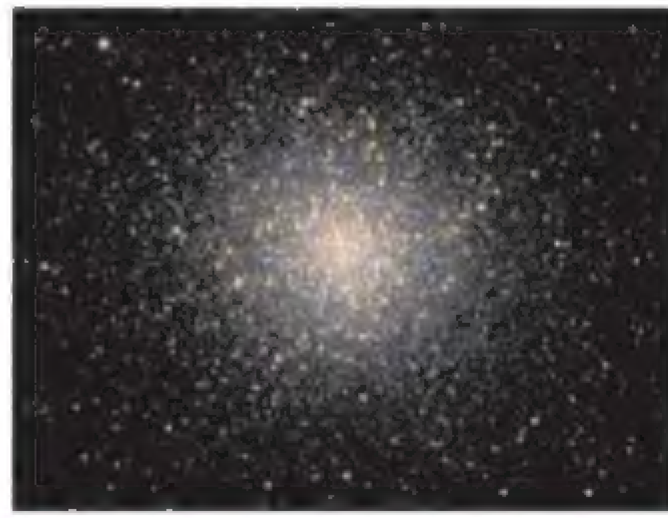
Do you know?

Light takes about 1 s to reach us from the moon while it takes 8 minutes to reach us from the Sun. It takes 4.2 years to reach us from the star alpha Centauri which is the star closest to the Sun.

Do you know?

When a gas sphere contracts, its temperature increaes. This happens because of transformation of its gravitational potential energy into heat energy.

More than one star can be produced by the contraction of a huge interstellar cloud. Figure 19.4 shows a cluster of thousands of stars. Most of these stars have formed from a single gigantic interstellar cloud.



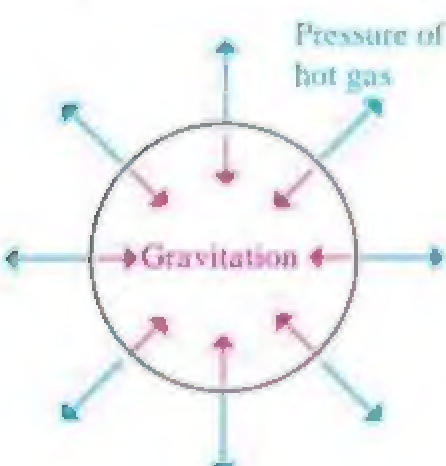
19.4 : A large cluster of stars. Most of these stars have formed from a single interstellar cloud.

Can you recall?

What is meant by balanced and unbalanced forces?

Stability of stars : If we burn an incense stick in one corner of a room, the fragrance spreads all over the room instantaneously. Similarly, when we remove the lid of a vessel containing boiling water, the steam spreads in the surrounding region. This means that hot gas spreads everywhere. Then, why doesn't the hot gas in the stars disperse in space? And why have the properties of the Sun remained unchanged over the last 4.5 billion years?

The answer to these questions is the gravitational force. The gravitational force between the gas particles of the star keeps these particles together. If the gravitational force which is constantly trying to bring the gas particles close together and the pressure of the hot gas which is constantly trying do disperse the gas are balanced, then the star remains stable. The gravitatinal force is acting inwards, towards the centre of the star while the gas pressure is acting outwards, i.e. away from the centre of the star (see figure 19.5).



Think about it.

You must have played tug of war. In this, two ends of a rope are pulled on two sides by two groups. When the forces applied by both sides are equal, they balance each other and the centre of the rope remains static. When the force on one side of the rope is larger than that on the other side, the centre of the rope moves towards that side. Something similar happens in the case of a star. When the gravitational force and gas pressure are balanced, the star is stable. But when one of them is more than the other, the star either contracts or expands.

Do you know?

1. If there was no gas pressure in the Sun, it will collapse to a point in 1-2 hours.
2. Gas pressure depends on the density and temperature of the gas. Higher the temperature and density, higher is the pressure.

Evolution of stars

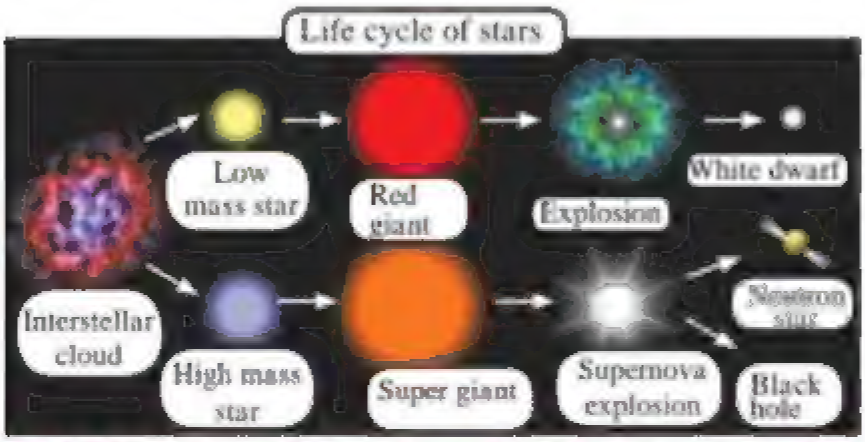
Evolution of a star means change in its properties with time resulting in its passing through different stages. We have seen that the properties of the Sun have not changed in the past 4.5 billion years. Stars evolve very slowly for most of their life time. As stars are continuously emitting energy, their energy is constantly decreasing.

For their stability to remain intact i.e. for maintaining a balance between the gas pressrue and the gravitational force, it is necessary that the temperature remains constant. For the temperature to remain constant, energy must be generated inside the star. This generation of energy occurs because of burning of fuel at the centre of the star. The reason for the evolution of stars is the burning of and therefore, the decrease in the amount of fuel in their centre. When the fuel in the centre finishes, the energy generation stops. As a result, the temperature of the star starts decreasing. Due to the decrease in temperature, the gas pressure decreses and the balance between gas pressure and gravitatinal forece cannot be maintained. As the gravtational force is now higher than the gas pressure, the star starts contracting. This causes another fuel to start burning e.g. when hydrogen at the centre is finished, helium starts undergoing fusion and energy generation starts again. How many fuels will be used depends on the mass of the star.

Higher the mass of the star higher is the number of fuels used. During this a lot of changes occur in the star. As a number of precesses occur inside the star, it sometimes contracts and expands at other times and the star goes through different stages. When all possible fuels are exhausted, the energy generation finally stops and the temperature of the star starts decreasing. The balance between gravitational force and gas pressure cannot be maintained. Let us now see how the evolution of the stars ends and what the end stages of stars are.

End stages of stars : The higher the mass of the star faster is its rate of evolution. The different stages during the evolution of the star which is the path of evolution of the star, also depends on its mass. How does the evolution finally stop?

We have seen that when the energy generation stops, the temperature decreases causing the gas pressure to decrease. The star contracts and its density increases. When the density becomes very high, some new types of pressures are generated which do not depend on the temperature of the gas. In such case, the gas pressure remains constant even after the energy generation stops completely and the temperature of the gas goes on decreasing. The stability of the star can remain intact for ever and this can be considered as the end stage of a star.



There are three ways of evolution of stars depending on their initial mass. Thus, we can divide stars in three groups. The path of evolution and end stage for all stars in the same group is the same. Lets us learn more about it.

19.6 Evalution of stars based on their mass and their end stages

1. End stages of stars having initial mass less than 8 time the mass of the Sun ($M_{star} < 8 M_{Sun}$) : Stars in this group undergo huge expansion and their radius increases by a factor of 100 to 200. In this stage they are called red giant stars. This name is given because of the large size and because of the fact that the stars look reddish due to their lower temperature. The size of a red giant star in comparison to other types of stars is shown in figure 19.2. At

the end of its evolution, these stars explode and their outer gas envelope is thrown out. The inner part contracts and its size becomes similar to the size of the earth. As the mass of the star is much higher than that of the earth and the size is similar to that of the earth, the density in the star becomes very high. In this state, the pressure due to the electrons in the star becomes independent of temperature and is able to balance the gravitatinal force for ever. In this state, the star looks white and due to its small size it is called a white dwarf. After this its temperature keeps decreasing but its size and mass remain unchanged for ever and so white dwarf is the end stage of stars in this mass range.

19.7 : The outer gaseous envelop which is thrown out during the formation of a white dwarf which is at the centre.

Do you know?

When the sun will become a red giant, its diameter will increase so much that it will swallow Mercury and Venus. It is possible that the earth will also be absorbed by the Sun. It will take 4-5 billion years for the Sun to reach this state.

2. End stages of stars having mass between 8 and 25 time the mass of the Sun ($8\ M_{Sun} < M_{Star} < 25\ M_{Sun}$) : These stars also go through the red giant stage and later through the supergiant stage during which their size may increase 1000 times. The huge explosion, called the supernova explosion, which occurs at last is very powerful and so much energy is given off that we can see the star during the day also.

The central portion which is left behind after the explosion, contracts and its size becomes as small as about 10 km. In this state, the stars are completely made up of neutrons and are called neutron stars. The pressure of these neutrons is independent of temperature and is capable of balancing the gravitatinal force for ever. Neutron star is the end stage of these stars.

19.8 A recent picture of the supernova explosion which was first seen in 1054 A.D.

Do you know?

1. As the size of the white dwarfs is similar to that of the earth, their density is very large. One spoonful material of the white dwarf will weight a few tons. As neutron stars are much smaller than the white dwarfs, their density is even higher and one spoonful material of these stars will weigh as much as the weight of all living beings on the earth.
2. A star in our galaxy exploded about 7500 years back. As the star is about 6500 light years away from us, the light emitted in the explosion took 6500 years to reach us. It was first seen on the earth by the Chinese in the year 1054. It was so bright that it could be seen during the day also for 2 years. After 1000 years of the explosion, the gases emitted during the explosion are seen to be expanding with velocities higher than 1000 km/s.

3. End stages of stars having mass larger than 25 times the mass of the Sun ($M_{star} > 25\ M_{Sun}$)

These stars evolve like the stars in the second group but after the supernova explosion, no pressure is capable of balancing their huge gravitational force and they continue contracting for ever. As their size becomes smaller, their density and their gravitational force increase tremendously. All nearby objects get attracted towards these stars and nothing can come out of them, not even light. Also, any light falling on these stars does not get reflected and gets absorbed inside the star. Thus, we cannot see the star at all but can probably see a minute black hole at its place. This end stage of the star is therefore, called a black hole.

Thus, we have seen that, depending on mass, there are three paths of evolution and three end stages of stars. These are shown in the following table.

Initial mass of the star	End stage of the star
$< 8\ M_{Sun}$	White dwarf
Between 8 to 25 M_{Sun}	Neutron star
$> 8\ M_{Sun}$	Black hole

Exercises

1. Search and you will find.

a. Our galaxy is called.........

b. For measuring large distances........ is used as a unit.

c. The speed of light is .... km/s.

d. There are about .... stars in our galaxy.

e. The end stage of the Sun will be......

f. Stars are born out of ..... clouds.

g. Milky way is a .... galaxy.

h. Stars are spheres of .... gas.

i. The masses of other stars are measured relative to the mass of the.............

j. Light takes .... to reach us from the Sun while it takes........... to reach us from the moon.

k. The larger the mass of a star the faster is its.......

l. The number of fuels used in the life of a star depends on its............

2. Who is telling lies?

a. Light year is used to measure time.

b. End stage of a star depends on its initial mass.

c. A star ends its life as a neutron star when the pressure of its electrons balances its gravity.

d. Only light can emit from the blank hole.

e. The Sun will pass through the supergiant stage during its evolution.

f. The Sun will end its life as a white dwarf.

3. Answer the following question.

a. How do stars form?

b. Why do stars evolve?

c. What are the three end stages of stars?

d. Why was the name black hole given?

e. Which types of stars end their life as a neutron star?

4. A. If you are the Sun, write about your properties in your own words.

B. Describe white dwarfs.

Project :

1. Use your imagination and make models of the Milky Way and the solar system.
2. Write the effects : If the Sun disappears ....